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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 4-90

EVALUATION OF MAKO 9700 HIGH PRESSURE BREATHING AIR COMPRESSOR

GEORGE D. SULLIVAN

MARCH 1990

NAVY EXPERIMENTAL DIVING UNIT

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

IN REPLY REFER TO:

NAVSEA TASK 89-11

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 4-90

EVALUATION OF MAKO 9700 HIGH PRESSURE BREATHING AIR COMPRESSOR

GEORGE D. SULLIVAN
MARCH 1990

Approved for public release; distribution unlimited

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

In response to reference (1) and as outlined in reference (2) the Navy Experimental Diving Unit (NEDU) tested the MAKO 9700 electrical powered high pressure, breathing air compressor from 26 Dec 89 to 9 Jan, 90. The purpose of this test was to determine if the equipment was suitable for use by the United States Navy (USN) diving community and for adding to the Approved for Navy Use (ANU) Procurement List.

The MAKO 9700 met manufacturer's specifications for quantity of air produced with a quality which met or exceeded purity standards in reference (3). The design and engineering were determined to be adequate. With the inclusion of the recommendations in section V, the MAKO 9700 compressor is considered suitable for USN requirements for compressors of this size and type.

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ILLUSTRATIONS

I. INTRODUCTION

In response to reference (1) and as detailed in reference (2), the MAKO 9700 compressor was tested by NEDU. The test was to determine if the compressor discharged suitable breathing air and had a service life which satisfied the requirements for divers air supply compressors throughout the Navy. Other material variations were also evaluated and are listed as considerations in Section V.

Highly portable divers air compressors are designed to have high pressure with relatively low volume outputs. Divers require low pressure with high volume. The average divers high pressure air compressor is connected to large volume high pressure air storage flasks to meet this need. In normal operation the high pressure air is reduced to a lower pressure to act as a breathing media for divers. As this is accomplished, the pressure gradually reduces in the storage flasks. The compressors tend to run on a continuous basis as the diving day continues because the demand is usually greater than the supply. At the end of the diving day or when air requirements are reduced, the compressors will exceed the demand and fill the air flasks.

There are various methods of testing compressor capacities. For the purposes of this compressor test, NEDU chose compressor testing consisted of charging from 0 to 2500 psig daily then opening the vent and maintaining 1500 psig for continuous run. This method more closely simulated the use a compressor would experience in the field. Additionally during the continuous run, random charge rates were taken from 2000 to 2500 psig. The compressor was operated a total of 50 test hours. The testing included subjective evaluation of the system operation but did not include detailed mechanical review of the individual components of the system.

II. EQUIPMENT DESCRIPTION

The MAKO 9700 high pressure, breathing air compressor (Figure 1) is of a four stage, two cylinder, "vee" configuration. The 1st and 4th stages are housed in one common stepped cylinder. The 2nd and 3rd stages are housed in the opposing stepped cylinder. All stages are lubricated by means of the force-fed lubrication system. The compressor requires approximately 2 quarts (US) of lubricating oil. The manufacturer recommends that only specific lubricants be used. These oils are not stocked in the Federal Supply System. Mako suggests Anderol 500 synthetic oil as a temporary substitute after 50 hours of run time. Anderol is a USN item. At the present time, 2190 TEP is the only lubricant authorized for breathing compressor use by the U S Navy.

The MAKO compressor block is common to the breathing air unit as well as industrial high pressure compressor units. It is particularly suitable for continuous operation because of its rugged design and the corrosion resistant intermediate filter and cooler assemblies.

The prime mover is a Baldor 25 horsepower, three phase 460/220 volt, 3525 RPM electric motor. Rotational torque is transferred to the compressor by a single banded belt.

Filtration system is a three chambered unit constructed of aluminum alloy, designed for 5000 psi working pressure. The first chamber is a mechanical separator to remove oil and water. Subsequent chambers utilize replaceable cartridges to remove water vapor, hydrocarbons, noxious gases, taste and odor. Carbon monoxide is also eliminated by catalytic oxidation. The final chamber includes a visual moisture and carbon monoxide indicator.

A pressure maintaining/non-return valve is provided down stream from the filter system to ensure that pressure build up occurs in the filters during start up and initial compressor air delivery. This achieves constant, optimum filtering, moisture separation, and prevents compressed air from returning from the charged air storage tanks to the compressor during unit shut down.

All four stages of the compressor are protected by safety relief valves. Figure 2 provides a diagram of the compressor purification system. For these tests the MAKO 1803 and 1503 filters were used.

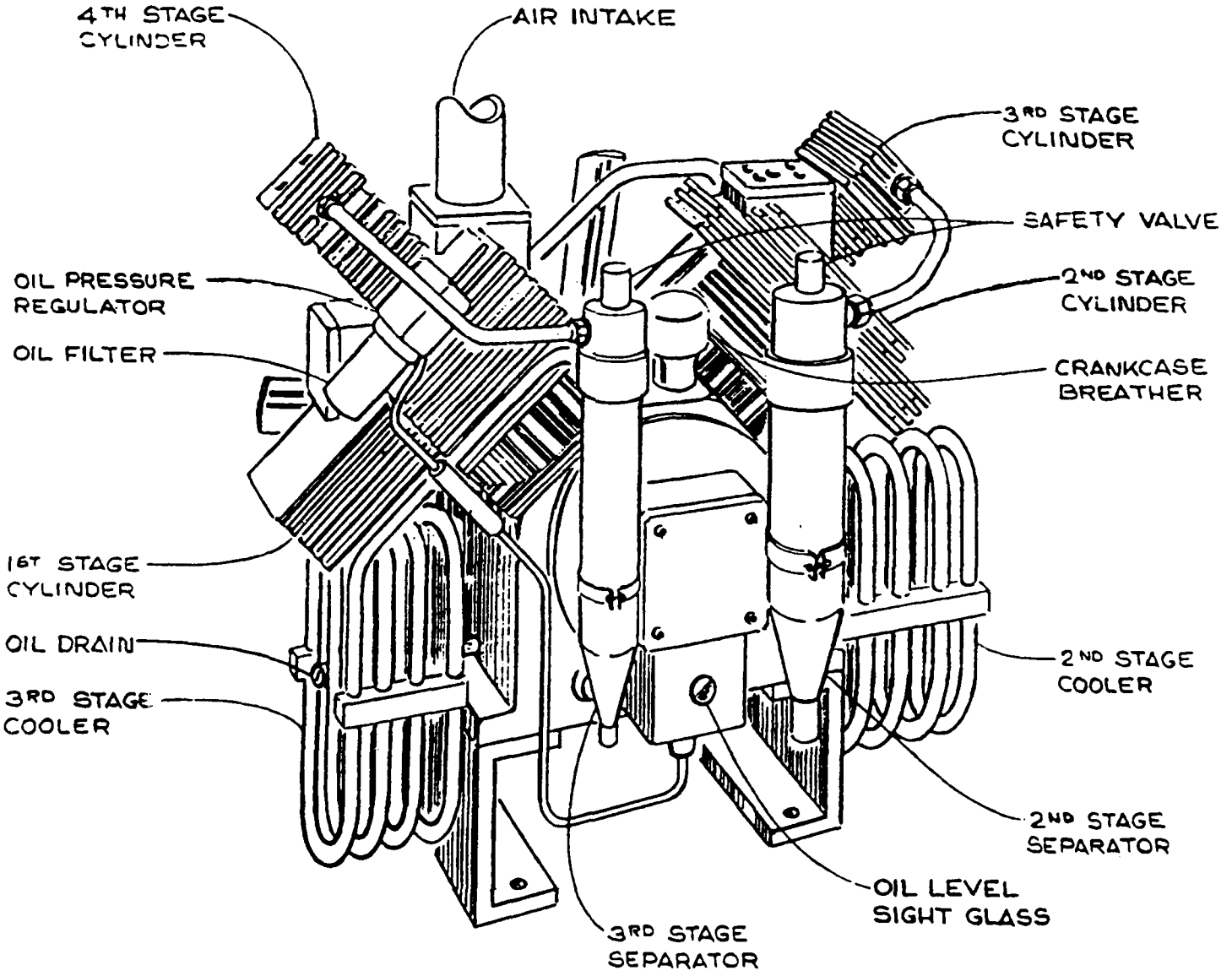
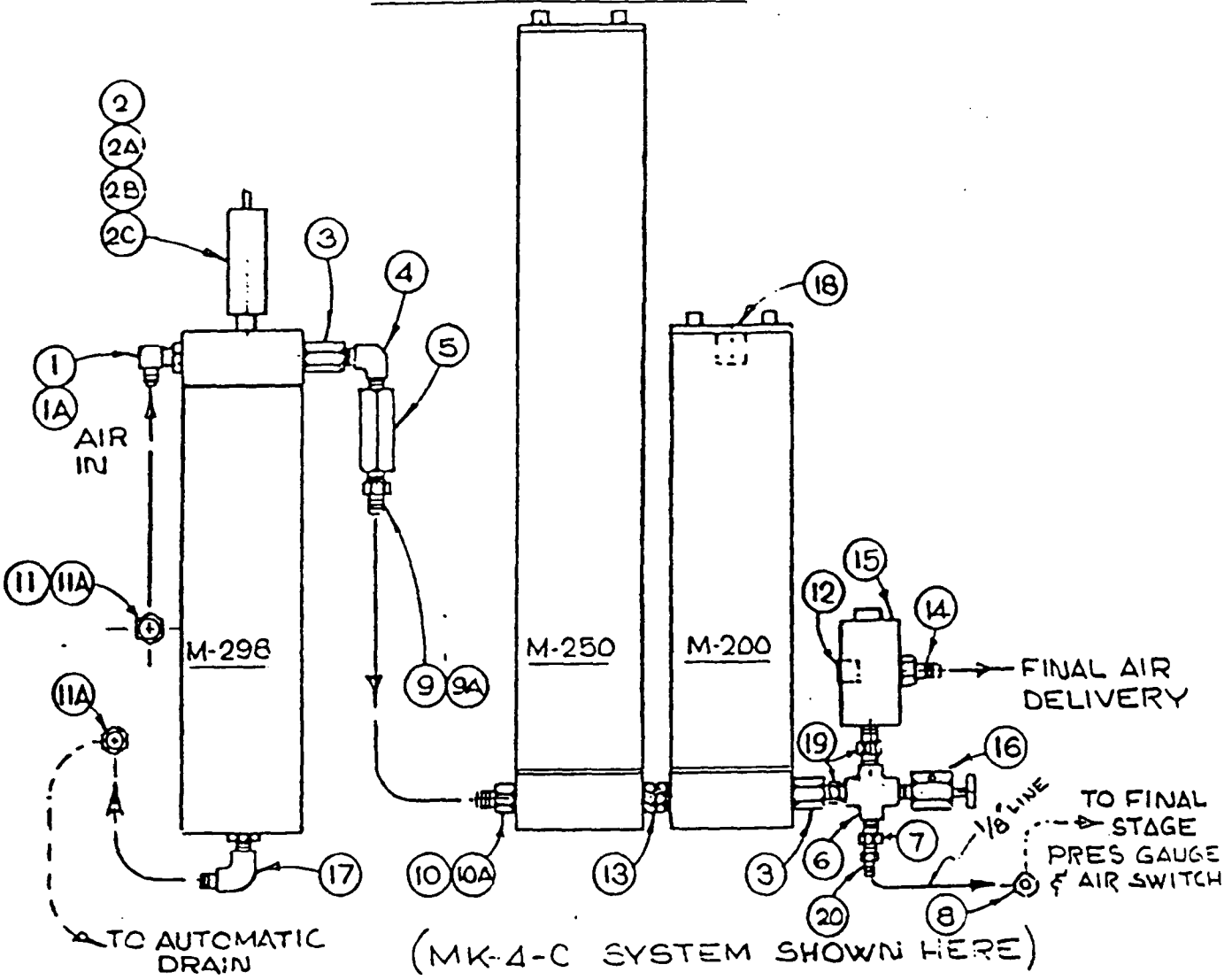

4TH STAGE CYLINDER
AIR INTAKE
3RD STAGE CYLINDER
SAFETY VALVE
OIL PRESSURE REGULATOR
2ND STAGE CYLINDER
OIL FILTER
CRANKCASE BREATHER
1ST STAGE CYLINDER
OIL DRAIN
2ND STAGE COOLER
3RD STAGE COOLER
2ND STAGE SEPARATOR
OIL LEVEL SIGHT GLASS
3RD STAGE SEPARATOR

Figure 1

PURIFICATION SYSTEM



1	M1303	90° Fitting (3/8 DIA. Line)
1A	M1303-1	90° Fitting (1/4 DIA. Line)
2	M2708	Safety Valve (3600 PSI)
2A	M2708-1	Safety Valve (5250 PSI)
2B	M2708-2	Safety Valve (5450 PSI)
2C	M2708-3	Safety Valve (4500 PSI)
3	M1301	Adaptor Fitting
4	M1359	90° Pipe Fitting
5	M4810	Check Valve
6	M1355	Cross
7	M1345	Fitting (1/4 to 1/8 Reduce)
8		Bulkhead Fitting (1/4)
9	M1320	Fitting 3/8 DIA. Line)
9A	M2001	Fitting (1/4 DIA. Line)
10	M1302	Fitting (For 3/8 DIA. Line)
10A	M1302-1	Fitting (For 1/4 DIA. Line)
11	M1319	Bulkhead Fitting (For 3/8 DIA. Line)
11A	M1372	Bulkhead Fitting (For 1/4 DIA. Line)
12	M1358	Plug
13	M1315	Union Fitting
14	M2001	Fitting
15	M3	Back Pressure Valve (Pressure Maintaining Valve)
16	M9400	Drain Valve
17	M1303-1	90° Fitting
18	M7413	H_2O/CO Indicator (Filter Top Type)
19	M1357	Fitting
20	M1330	Fitting

Figure 2

III. TEST PROCEDURE

The compressor and all ancillary equipment was received and set up in accordance with the manufacturer's instructions. A Cole Palmer model 8502-14 temperature monitor and Yellow Springs Instruments 700 series thermistor probes were attached to measure compressor discharge and ambient temperatures. A safety line was installed on the charging whip. The unit was placed in an exterior work area, open to ambient temperature but protected by an awning from direct weather. APPENDIX A contains the complete test plan and the pass/fail criteria used during the evaluation. APPENDIX B is the test log and contains the recorded data.

A. ENDURANCE TEST

The compressor was operated daily to charge four 2250 cubic inch (floodable volume) cylinders. The four cylinders were interconnected to simulate one large 9000 cubic inch air flask. After a charge of 2500 psig on the flasks the vent was opened and the compressor run at 1500 + psig. Since the filter flasks hold 1500 psig the charge rate was verified by charging from 1500 to 2500 psig. A total of 50 hours of operation were logged on the compressor. The following parameters were recorded

1. Date
2. Time
3. Total meter hours
4. Total test hours
5. Oil level
6. Oil pressure
7. All four stage pressures
8. Discharge air temperature
9. Ambient air temperature
10. Flask size
11. Flask pressure

B. CHARGE RATES

The volume of air delivered and the time to achieve that volume was logged daily.

C. OIL CONSUMPTION

At the beginning of the test the oil sump level was measured as full (3/4 of sight glass). Oil level was monitored during operations and consumption logged. An oil change was accomplished (as per manufacturer's recommendations) at 25 hours of compressor operation. The oil used for the change was MAKO regular compressor oil.

D. AIR SAMPLING

Air samples were taken from the compressor discharge at hours 1, 25 and 50 and sent to the NCSC Laboratory, Code 5130, for purity analysis.

E. MAINTENANCE

Scheduled maintenance was performed in accordance with the manufacturer's instructions and consisted of a lubricating oil change at 25 hours of operation, and a filter change at 32 hours of testing. The oil sump level, CO2/moisture indicator was checked prior to start-up each day.

IV. RESULTS

A. ENDURANCE TEST

The compressor was successfully operated at a total of 50 hours per appendix "B" to insure proper functioning and to draw air samples.

B. CHARGE RATES

The data collected provided a complete operational and maintenance log for this test and was the basis for computing and evaluating all the test results. Compressor charge rates for the air cylinders used during the test were as follows:

	TIME	TOTAL VOLUME	CHARGE RATE
MAXIMUM:	5 MINUTES 36 SECONDS	177 CUBIC FEET	32.68 CFM
MINIMUM:	5 MINUTES 25 SECONDS	177 CUBIC FEET	31.57 CFM
AVERAGE:	5 MINUTES 29 SECONDS	177 CUBIC FEET	32.27 CFM

NOTE: Differences in maximum and minimum charge rates were the result of differences in the ambient temperature at the time the charge rates were taken and not considered significant.

The majority of the temperature differentials between ambient and compressor discharge temperatures were 5 to 8 degrees Fahrenheit. The maximum recorded differential temperature was taken immediately after startup. It is not considered to be a true reading because of the temperature drop of compressed air dumping to empty flasks from the 1500 psig build up in the filter system.

C. OIL CONSUMPTION

During the test the compressor consumed one quart of oil. Average consumption was 0.04 pints per hour and is considered acceptable.

D. AIR SAMPLING

The results of the air samples are shown in APPENDIX D. All samples were within limits established by reference (3).

E. MAINTENANCE

The MAKO 9700 compressor unit was easily maintained and only minor problems were encountered. The maintenance manual for the compressor is considered adequate.

NOTE: During test hour 23 the oil pressure dropped below 1000 psi. As suggested by the manual the pump was vented with no increase in oil pressure. The oil pressure regulator set screw was used to adjust the pressure in accordance with manufactures instruction manual and no further oil pressure problems occurred.

V. RECOMMENDATIONS

The following are recommended considerations that the user should be aware of when purchasing this compressor.

Depending on the specific use and environment it may be prudent to have the manufacturer make the recommended changes prior to purchasing the compressor.

A good example of this would be if the compressor was going to be used inside a protected area the recommendations would not apply as much if it was going to be used out in the weather.

These are only considerations and not requirements.

A. Primary power source be changed to meet specifications standards of MIL-M-17060-E Amendment 1.

Justification

Reference (4). To meet Navy specifications the prime mover, if electric, should be a sealed insulation system (service A use) in accordance with MIL-M-17060 E, Amendment 1.

B. The cadmium coated fittings be replaced with a suitable substitute.

Justification

Reference (5) states that cadmium coated fittings cannot be used in systems that exceed 400 degrees Fahrenheit or if the cadmium could come in contact with petroleum products. At this time the only authorized HP compressor lubricant by the Navy is 2190-TEP. Also, if subjected to sea spray cadmium coated fittings are susceptible to corrosion.

VI. CONCLUSIONS

Evaluation of the MAKO 9700 compressor revealed the following:

1. The MAKO 9700 compressor delivers acceptable breathing air at a charge rate and volume which meet's or exceeds the manufacture's specifications.
2. The unit is sturdy, reliable and readily maintained

3. The operating and maintenance manuals for the compressor are adequate.
4. The MAKO 9700 compressor is suitable for use by the US. NAVY.

VII. REFERENCES

1. NAVSEA Task 89-11; Testing of commercially available air compressors for divers use for ANU list.

2. Test Plan Number 89-53; Operational Evaluation of Divers High Pressure Air Compressor.

3. NAVSEA 0994-LP001-9010, U S Navy Diving Manual Vol 1 Para 5.3.2. Air purity standards.

4. MIL-M-17060 E, Amendment 1, Sealed insulated systems, (service A use). Navy specifications for compressor power source.

5. Navy Publication No. S9AA-AA-SPN-010/GENSPEC of Jan 19, 1987. General Specifications for Ships of the Navy, Cadmium Fittings

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

IN REPLY REFER TO:
NAVSEA Task 89-11

NAVY EXPERIMENTAL DIVING UNIT

STANDARD TEST PLAN

EVALUATION OF COMMERCIALLY AVAILABLE AIR COMPRESSORS FOR USE IN DLSS

TEST PLAN NUMBER 89-53

DECEMBER 1989

Submitted:	Reviewed:	Approved:
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DISTRIBUTION: Codes 00, 01, 02, 03, 04, 05
Original to Technical Library

RECORD OF CHANGES

Except as provided for herein, changes will be made only on the authority of the Commanding Officer, NEDU. A dark vertical line in the left-hand margin indicates the coverage of change.

CHANGE	AUTHORITY	INSERTION	SECTION	INITIAL

TABLE OF CONTENTS

References:

(a) NAVSEA OOC MEMO Task 89-11 Evaluation of Commercially Available Divers Air Compressors
(b) NAVAL EXPERIMENTAL DIVING UNIT TEST EVALUATION NUMBER 80-37
(c) NAVAL COASTAL SYSTEM CENTER Field test procedure SP80-13-OS6 for testing Diving Air Compressors
(d) Mako Publication Number 54089 M 89 A, for Model 9700 Electric drive High Pressure Air Compressor.

1. Introduction. This test plan provides a series of procedures for standardized evaluation of commercially available divers high pressure air compressors. The compressors will be evaluated and data compiled during these test to determine their suitability and reliability; and possible approval for Navy use (ANU).

NAVSEA OOC Memo Task 89-11 directed NEDU to survey the commercial domestic market to determine if currently available high and low pressure compressors are applicable for fleet use. If applicable procure compressor systems as required for evaluation. Make recommendations for inclusion on Approved for Navy Use (ANU) listings.

2. Test Parameters. Evaluation of the compressor will be conducted as follows:

a. Receipt of compressor at NEDU, Panama City.

b. Conduct inspection of compressor using manufactures instruction manuals as references to ensure all parts and material are received and on hand.

c. Using the manufactures technical manual for the specific air compressor and it's components, inspect for and determine if the following items exist and/or comply, and record results and comments in Appendix A:

(1). All instruments and controls are clearly and permanently marked according to their functions

(2). All controls, gauges and indicators necessary for operation of the compressor are visible and convenient to the operator.

(3). Safety devices are provided and audible and/or visual warning functions as specified

(4). Liquid level indicators accurately display liquid level.

(5). All removable components can be removed and properly re-installed in working conditions using the manufacturer's operating manual i.e. filters

(6). All drain, trap and safety valve discharge ports will function without splashing, are conveniently located, and are away from operating personnel.

d. Have all instrumentation provided by manufacturer compared and calibrated by N.A.R.F. Pensacola Naval Air Station

e. Operate the compressor for one (1) hour under a no load condition

f. Take air samples following no-load test run, and have the analysis conducted by NCSC Gas Analysis Laboratory.

g. Conduct Testing in accordance with the procedures set fourth in section 4. Total compressor running time will be 50 hours.

3. Preliminary Arrangements

a. Arrange for air analysis to be conducted by N.C.S.C. as required

b. Arrange for all instrumentation to be calibrated by calibration facility

c. Prior to the actual test procedure the air compressor system shall be operated then shut down when the system is at maximum pressure and the following steps accomplished.

(1) Hold pressure
(2) Allow the system to cool to ambient temperature
(3) After temperature has stabilized, record the storage flask pressure.
(4) After an eight hour period, record pressure again
(5) Leak rate shall be Zero

4. Test Procedure. The following test procedures will be conducted as specified, and the results entered in the log sheets, annex A

a. Take air samples at hours 1, 25, 50 and anytime air quality is questioned

b. Log the following measurements on the log sheet annex A

(1) Date

(2) Time

(3) Compressor meter hour (if applicable)

(4) Total hours running time on compressor (this test)

(5) Compressor oil level

(6) Compressor oil pressure

(7) 1st Stage pressure

(8) 2nd Stage pressure

(9) 3rd Stage pressure

(10) 4th Stage pressure

(11) Discharge air temperature

(12) Ambient air temperature

(13) Flask size and pressure

(14) Remarks

c. The compressed air system shall be set to run at 1500 psig adjusting controls and bleed off rate.

d. Compute volume output of the compressor by charging a known volume storage flask to 3000 psig. Log total charging time and calculate charging rate.

e. Oil consumption shall be measured and recorded during testing, with measurements and additions entered in the log.

f. Perform maintenance as required by the manufactures instruction manuals.

5. Post Test Arrangements. Make all necessary arrangements as previously determined to return compressors system and test fixtures to proper locations.

6. Personnel Requirements. NEDU Hyperbaric and/or Test and Evaluation Department personnel (1 each)

7. Safety Rules and Emergency Procedures. Safety rules and precautions as outlined in the specific manufactures instruction manuals

8. Logistical Support. Air Analysis (NCSC Analysis Lab)

9. Funding Source. NAVSEA OOC TASK NO. 89-11

10. Report Production. Test report and camera ready copy to be written and prepared by the Test Director and submitted for approval to the Commanding Officer via the Task Leader. Estimated publication date is six (6) weeks following completion of testing. Test Directors will be the point of contact for NEDU concerning this test and will be appointed by the Task Leader.

11. Comments and Additional Information. The NEDU Task Leader and Test Director are responsible for the following:

a. Control and Safety of Systems. All control systems, safety systems and valves shall be activated by making the necessary temporary alterations to the compressor controls and operations whenever such alterations will not result in a risk of damage to the compressor unit. Where a risk is present, the test may be conducted with control systems completely removed from the compressor unit by subjecting control system sensors to other sources of temperature and pressure; for example, the oil safety switches and sensors, automatic condensate blow down valves overpressure switches and sensor, high temperature switches and sensors, and other devices designed to operate or protect the system and attending personnel.

b. Termination Criteria. The following is Failure Criteria for the suitability for the specific compressor system for ANU:

(1) Failure of any component which cannot be corrected in accordance with the recommended schedule of maintenance

(2) Failure of the diving air system to operate as specified by the manufactures instruction manuals

(3) Failure of the valves to operate as specified

(4) Failure of the pressure relief valves to operate as specified.

(5) A decrease in capacity of the compressor during this performance evaluation

(6) A discharge air temperature from any cylinder in excess of manufactures's specifications or recommendations.

(7) Failure of the air samples to pass breathing air specifications.

MAKO DIVERS AIR COMPRESSOR
MODEL K 27-9700

1989 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
12 26	0825	2.8	0	3/4	1000	38	210	850	1670	54.5	45	125	NO LOAS TEST (1500)
12 26	0855	3.2	:30	1/2	1025	40	220	860	1710	56.7	56.9	1400	VENT OPEN
12 26	0925	3.8	1:00	1/2	1025	40	220	860	1710	56.4	57.8	1400	STOP TAKE AIR SAMP
12 26	1030			3/4	1025	40	215	850	1700	32.6	56.2	125	READING AT 1 MIN
12 26	1130	4.8	2:00	1/2	1025	38	225	865	1700	64.6	75.6	1560	VENT OPEN
12 26	1230	5.8	3:00	1/2	1020	40	220	860	1700	63.0	73.2	1520	CLOSED VENT STOP
12 26	1300			3/4	1020	38	215	850	1580	60.2	71.1	1600	VENT OPENED START
12 26	1400	6.8	4:00	1/2	1020	38	220	860	1650	64.2	71.7	1530	VENT OPEN
12 26	1500	7.8	5:00	1/2	1020	40	220	860	1700	63.8	66.5	1540	VENT OPEN SECURE
12 27	0700			3/4	1050	41	220	840	1620	42.1	42.3	120	VENT CLOSED STAR
12 27	0800	8.8	6:00	1/2	1020	40	220	800	1650	51.7	45.4	1540	VENT OPEN
12 27	0900	9.8	7:00	1/2	1020	40	220	800	1650	53.5	47.6	1500	VENT OPEN
12 27	1000	10.8	8:00	1/2	1020	40	220	800	1650	59.8	52.0	1500	VENT OPEN
12 27	1100	11.8	9:00	1/2	1010	40	220	800	1620	67.1	59.6	1500	VENT OPEN

MAKO DIVERS AIR COMPRESSOR
MODEL K 27-9700

1989 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
12 27	1105	CHARG	RATE TIME 2000 TO 2500 :5::25							OPENED VENT			
12 27	1200	12.8	10:00	1/2	1010	40	220	810	1710	68.3	61.1	1540	VENT OPEN
12 27	1300	13.8	11:00	1/2	1010	40	220	810	1680	70.3	62.5	1500	VENT OPEN
12 27	1400	14.8	12:00	1/2	1010	40	220	820	1750	69.8	62.2	1640	ADD 4 OZ OIL
12 27	1430	15.3	12:30	1/2	1010	40	220	800	1650	67.7	60.6	1500	VENT OPEN SECURE
12 28	0700			3/4	1050	40	220	800	1650	42.6	44.3	150	READINGS AT 1 MIN
12 28	0800	16.3	13:30	1/2	1025	40	220	820	2560	55.3	44.6	2500	OPENED VENT
12 28	0900	17.3	14:30	1/2	1025	40	220	900	2310	55.6	45.3	2210	VENT OPEN
12 28	1000	18.3	15:30	1/2	1025	40	220	900	2300	58.0	47.1	2180	VENT OPEN
12 28	1100	19.3	16:30	1/2	1020	40	220	880	2050	62.2	55.8	1930	VENT OPEN
12 28	1200	20.3	17:30	1/2	1010	40	225	880	2020	69.5	59.3	1910	VENT OPEN
12 28	1201	CHARGING RATE 2000 TO 2500 :5::25								OPENED VENT			
12 28	1300	21.3	18:30	1/2	1010	40	220	800	1610	73.7	65.7	1500	VENT OPEN
12 28	1400	22.3	19:30	1/2	1010	40	220	800	1610	75.5	66.6	1500	VENT OPEN
12 28	1500	23.3	20:30	1/1	1000	40	225	810	1660	74.2	70.4	1600	VENT OPEN SECURE

MAKO DIVERS AIR COMPRESSOR
MODEL K 27-9700

1989 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
01 08	1000	43.5	40:40	1/2	1020	40	220	925	1880	64.5	58.2	1750	VENT OPEN
01 08	1005	CHARGING RATE 2000 TO 2500 :5::30										OPENED	VENT
01 08	1100	44.5	41:40	1/2	1020	40	225	940	1950	67.7	61.2	1840	VENT OPEN
01 08	1200	45.5	42.40	1/2	1020	40	225	940	1950	65.5	58.1	1860	VENT OPEN
01 08	1300	46.5	43:40	1/2	1020	40	220	910	1750	62.2	57.7	1630	VENT OPEN
01 08	1400	47.5	44:40	1/2	1020	40	220	900	1650	65.2	57.9	1550	VENT OPEN
01 08	1440	48.2	45:20	1/2	1020	40	220	900	1650	63.9	57.9	1500	VENT OPEN SECURE
01 09	0640			3/4	1050	40	220	880	1800	46.5	47.3	100	ADD 4 OZ OIL
01 09	0740	49.2	46:20	1/2	1020	39	220	910	1720	57.0	48.3	1700	VENT OPEN
01 09	0840	50.2	47:20	1/2	1020	40	220	900	1650	58.8	52.0	1530	VENT OPEN
01 09	0850	CHARGING RATE 2000 TO 2500 :5::36											OPENED VEB NT
01 09	0940	51.2	48:20	1/2	1020	40	220	900	1650	61.4	55.1	1530	VENT OPEN
01 09	1040	52.2	49:20	1/2	1020	40	220	900	1650	63.8	57.1	1550	VENT OPEN
01 09	1120	52.9	50:00	1/2	1020	40	220	900	1650	66.0	60.0	1550	SECURE AIR SAMPLE

Memorandum 27 December 1989

To: J. Schmitt, EDU
From: G. Deason, Code 5130

Subject: Analysis of air sample from Mako 9700 air compressor. Test #89-53. One hour sample.

1. In accordance with your request, on 26 December 1989 the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0 %
Nitrogen	78.1 %
Argon	0.9 %
Carbon Dioxide	12 PPM
Carbon Monoxide	<0.5 PPM
Total Hydrocarbons*	3.4 PPM
Total Halogens**	<0.5 PPM
Methane	3.4 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
C4+	<0.1 PPM

*Expressed as methane equivalents.
**Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason
Chemist

Memorandum 3 January 1990

To: J. Schmitt, EDU
From: G. Deason, Code 5130

Subject: Analysis of air sample from Mako 9700 air compressor. Test #89-53. Twenty-five hour air sample.

1. In accordance with your request, on 3 January 1990 the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0 %
Nitrogen	78.1 %
Argon	0.9 %
Carbon Dioxide	301 PPM
Carbon Monoxide	<0.5 PPM
Total Hydrocarbons*	3.0 PPM
Total Halogens**	<0.5 PPM
Methane	3.0 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
C4+	<0.1 PPM

*Expressed as methane equivalents.
**Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason
Chemist

Memorandum 18 January 1990

To: Dave Sullivan, NEDU
From: G. Deason, Code 5130

Subject: Analysis of air sample from Mako 9700 air compressor. 50 hour sample. Test #89-53.

1. In accordance with your request, on 18 January 1990 the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0 %
Nitrogen	78.1 %
Argon	0.9 %
Carbon Dioxide	282 PPM
Carbon Monoxide	<0.5 PPM
Total Hydrocarbons*	2.8 PPM
Total Halogens**	<0.5 PPM
Methane	2.8 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
C4+	<0.1 PPM

*Expressed as methane equivalents.
**Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason
Chemist

SPECIFICATIONS

UNIT DESIGNATION

A belt driven, high pressure, air cooled compressor — 5408 / 5409

TECHNICAL DATA

Type.....Four stage, four cylinder - V configuration

Cooling.....Fan activated air

Direction of rotation viewed from drive end.....Anti-clockwise

Type of valves.....Single & combined multi-ported

Intake silencer/air filter.....Dry

STAGE PRESSURES

	DELIVERY psig	1ST STAGE psig	2ND STAGE psig	3RD STAGE psig
5408	1000	25/29	160/180	600/690
	2000	26/30	165/185	700/790
	3000	26/30	170/190	790/880
	4000	26/30	175/195	840/950
	5000	27/31	185/210	885/995
5409	1000	35/39	205/230	720/820
	2000	36/40	215/240	800/880
	3000	36/40	220/245	870/970
	4000	36/40	225/250	935/1040
	5000	36/40	220/250	1000/1120

		5408	5409
Oil pressure.....psig		1000	1000
Inlet pressure.....max.psig		6	0.5
Safety valve set pressure - 1st stage.....psig		50	50
2nd stage.....psig		240	300
3rd stage.....psig		1400	1400
Final stage.....Supply + 10%			

GENERAL			5408	5409
Charging rate.....		ft3/m	24.5	29.0
(Charging a 6 litre cylinder.....		M3/hr	41.6	49.3
from zero to maximum pressure)				
First stage piston displacement....		ft3/m	30.3	36.4
		M3/hr	51.5	61.9
Compressor power.....	@5000 PSI	hp	19.2	23.0
		Kw	14.3	17.2
	@2100 PSI	hp	16.9	20.0
		Kw	12.6	14.9
Volume free				
air delivered.....	@5000 PSI	ft3/m	20.0	24.0
		M3/hr	34.0	40.8
	@2100 PSI	ft3/m	20.8	24.8
		M3/hr	35.3	41.1
Noise level at 3 meters.....		dB(A)	85	
Cooling air flow rate (approx).....		ft3/m	4120	5002
		M3/hr	7000	8500
Compressor heat to atmosphere.....		Btu/m	825	1050
		Kw	14.5	18.0
INCLINATION				
Permissible inclination of machine:				
Front to rear side.....		degrees	10	10
Left or right.....		degrees	20	20
DIMENSIONS				
First stage cylinder bore.....		in	4.12	4.53
		mm	105	115
Second stage cylinder bore.....		in	2.95	2.95
		mm	75	75
Third stage cylinder bore.....		in	1.10	1.10
		mm	28	28
Fourth stage cylinder bore.....		in	0.55	0.55
		mm	14	14
Stroke.....		in	2.2	2.2
		mm	56	56

Final delivery		5408	5409
O/D pipe connection.....	in	0.315	0.315
	mm	8	8
First stage suction connection.....	NPT	2	2
Compressor (bare) height.....	in	35.5	35.5
	mm	900	900

WEIGHT

Complete 9000 Series (approx).....	lbs	720	720
	kgs	326	326

SPEEDS

Compressor speed.....	rpm	1800	1800
Mean piston speed.....	ft/s	11	11
	M/s	3.35	3.35
Max acceptable vibration level in any direction on the valves.....	mm/s	40	40

TEMPERATURES

Ambient and air inlet temperature.....	min	F	14	14
		C	-10	-10
	max	F	113	113
		C	45	45

NOTE: It is extremely difficult to accurately record air temperatures by the surface metal temperature, due to air flow from the fan cooling down the reading. However, as a general guide, no metal surface temperature should exceed 160 C (338F).

LUBRICANTS

Recommended oil - mineral.....Mako Compressor Oil

Recommended oil - synthetic.....Mako Super Synthetic Oil

Sump capacity.....	pts	4	4
	ltrs	2.3	2.3

Recommended grease (for assembly)..Silicone